

Biology, Brain, and Behavior (Part I)

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Psychology 216

Lecture Overview

Influence of type and timing, as well as the consequences of experience on prenatal, neonatal, and infant development

- **Prenatal Development**
 - What are the basic stages associated with prenatal development?
 - What experiences influence prenatal development?
 - How does the brain develop prenatally?
 - What things can/does the infant learn prenatally?
- **Neonatal Development**
 - What physical and mental abilities are humans born with? What role does state of arousal play in early neonatal development?
- **Early Infant Development**
 - What is synaptic pruning and what are the consequences of pruning for behavior?
 - What are some examples of critical and sensitive periods in development and how are they different from each other?

PRENATAL EXPERIENCE AND DEVELOPMENT

Prenatal Development

- Development between conception and birth
 - ~37-40 weeks
 - < 37 weeks is considered preterm
- Broadly characterized by...
 - Most rapid physical growth at beginning; more specialized and detailed growth at end
 - More early development of the top half of the body (remember head to toe)
- Prenatal development is broken into three different periods
 - Germinal
 - Embryonic
 - Fetal

Stages of prenatal development (see Table 2.1)

- Stage 1: Germinal (conception to 2nd week)
 - Rapid cell division occurs; rapid increase of physical size
 - Organism: **Zygote**
 - Brain: Neural tube begins to form

Stages of prenatal development (see Table 2.1)

- Stage 2: Embryonic (3rd-8th week)
 - Cell differentiation-stem cells to specialized cells
 - Creation/development of major organs
 - Organism: **Embryo**
 - Brain: major brain development, growth, and sensitivity

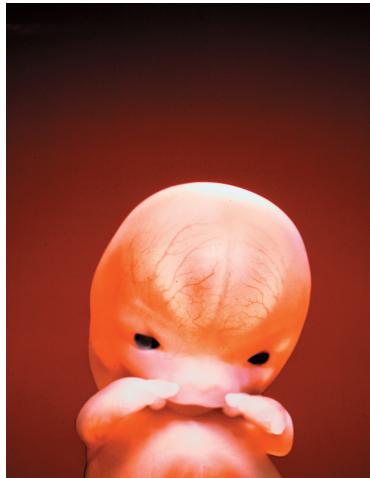
4 weeks



5 ½ weeks



8 weeks

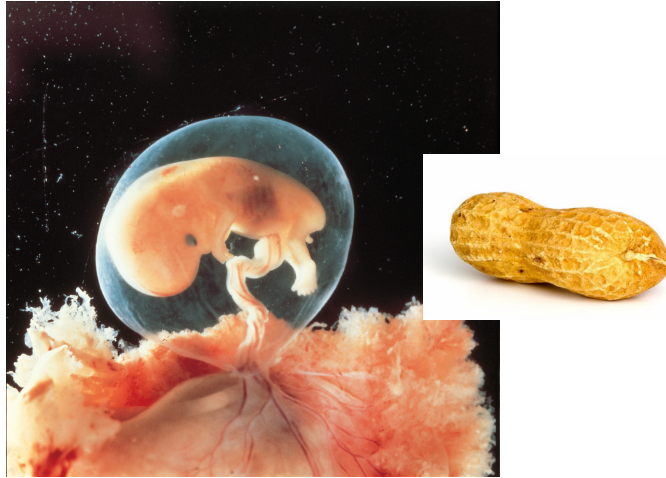


Stages of prenatal development

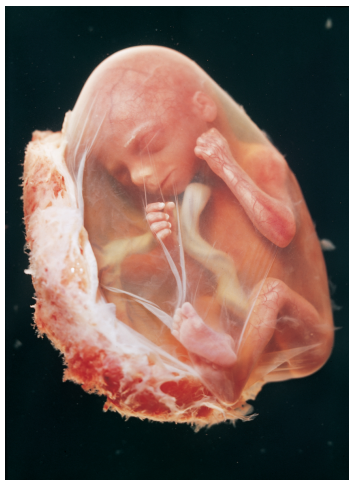
(see Table 2.1)

- Stage 3: Fetal (9th week to birth)
 - Longest stage
 - Upper body becomes more detailed; lower part of body develops
 - Organism: **Fetus**
 - Brain: Further structural organization, expansion, and folding

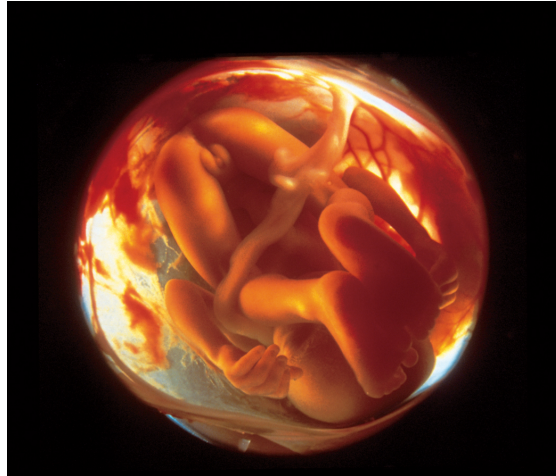
9 weeks



16 weeks



20 weeks



28 weeks



Fetal Brain Development Animation

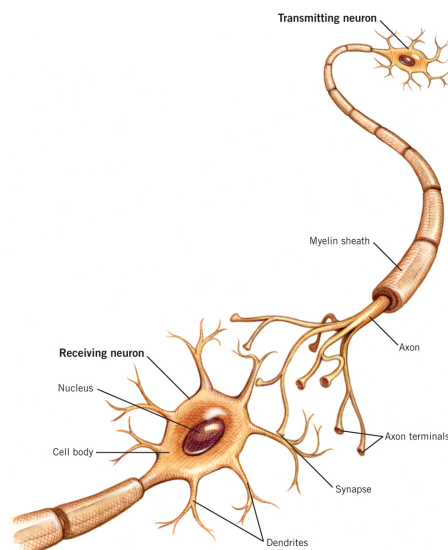
Brain Development Animation: Prenatal

Created by: Animated Biomedical Productions

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Neurogenesis/Synaptogenesis

- Neurogenesis-rapid growth of new neurons
- Synaptogenesis-rapid growth of connections between neurons
- Explosion of new neurons and connections during prenatal development
- Both continue, to a lesser extent, into maturity



Rich Fetal Experience

- Sights
 - Negligible/too dark for much experience
- Touch
 - contact with self
- Taste-
 - amniotic fluid ingested and tasted
- Smell
 - Sensitive to smells in amniotic fluid/food ingested by mother
- Hearing
 - Sensitive and responsive to sounds

Fetal Perception and Learning

- Learn and prefer familiar smells
- Long-lasting preferences for tastes experienced prenatally
- Learn linguistic patterns and sounds

Smell and Learning

- Fetus inhales amniotic fluid
- Like taste, smells are introduced through in amniotic fluid
- Smells appear to be learned, as newborns prefer to the smell of amniotic fluid from own mother over fluid from another mother

Lasting Taste Preferences

- Fetus swallows amniotic fluid
- Taste continually changing, influenced by contents including...
 - What mother eats
- 5 month olds prefer taste exposed to in womb
 - Ex: prefer carrot juice if administered during pregnancy,

Fetal Hearing and Learning

- Heart rate of fetus decreases to syllable changes
- Newborns prefer to hear a story read to them in the womb
 - DeCasper & Spence (Cat in the Hat)
- Newborns prefer to hear their native language over a foreign language
- Newborns prefer mother's voice over stranger's voice

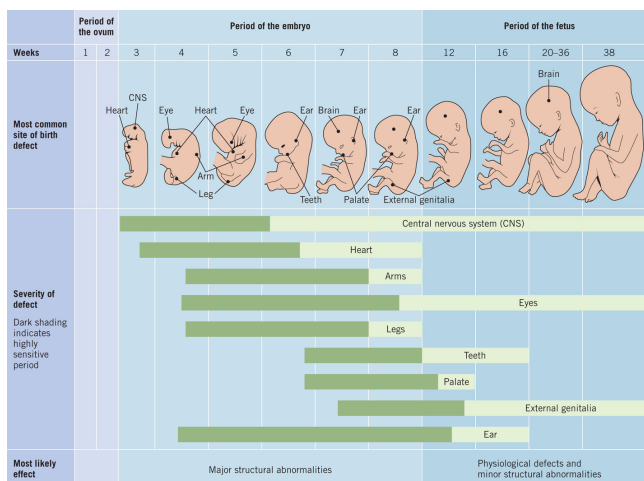
Environmental influences on prenatal development

Two important concepts:

Dose-response relation-amount of exposure is important to the outcome

Sensitive Periods-timing of exposure is important to the outcome

Nature vs. Nurture: Prenatal Vulnerability



Why do you think 3-8 weeks is the most vulnerable time for the organism?

- What might be the advantages for survival of vulnerability during this time window?
- Disadvantages?

Teratogens

- Drugs
 - Alcohol
 - Tobacco
 - Other illegal drugs
- Pollutants
- Occupational
 - EX: Toll booth collectors-exhaust from car

Maternal Risk Factors

- Age
 - too young or too old may cause problems
 - Linked to variety of chromosomal abnormalities
- Nutrition
 - Lack of general nutrition associated with smaller brains
- Emotional State
 - Higher distress during pregnancy related to behavioral problems at age 4

Poverty

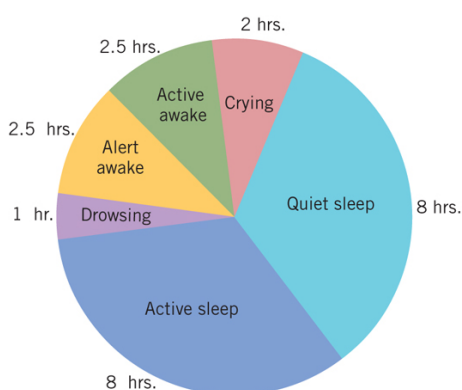
- Multiple risks associated with low socioeconomic status (SES)
 - Outcome is generally less positive for infants of lower SES parents
- Why?
 - Low SES **correlates** with a variety of risk factors
 - Drug use, exposure to harmful chemicals, harsh working environment
 - Access to healthcare, education about nutrition, illness, emotional distress, etc.

Questions on prenatal development?

NEONATAL EXPERIENCE AND DEVELOPMENT

Neonatal development

- Neonate = newborn
 - birth to ~1 month
- Development during this period is a constant interaction between **state of arousal** and experience
- 6 main states of arousal



Sleep and learning

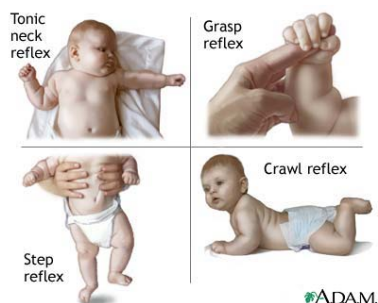
- Visual learning?
 - Spend ~50% of sleep time in REM
 - compared to about 20% at 3-4 years
 - May allow for further visual stimulation/development
 - Extra high level visual experience during wake hours decreases the time neonates spend in REM sleep (Boismeyer, 1977)
- Auditory learning?
 - Some of the time brains do not disconnect from external auditory stimuli
 - EEG brain activity showed that infants exposed to foreign vowels sounds during sleep later recognized those sounds
 - fNIRS/fMRI used to show language-specific activity in sleeping

Neonatal Reflexes

- Reflexes: Unlearned, involuntary response to stimulus that is common to all members of a species
- Absence or impairment of reflex is a sign of deeper neurological impairment

Neonatal reflexes

- Approach
 - Breathing
 - Rooting (see video)
 - Sucking
 - Swallowing
- Avoidance
 - Coughing
 - Sneezing
 - Blinking
- Other
 - Palmar grasp
 - Babinski toe fanning
 - Moro response
 - Tonic neck reflex
 - Stepping
 - Facial imitation (see pictures)



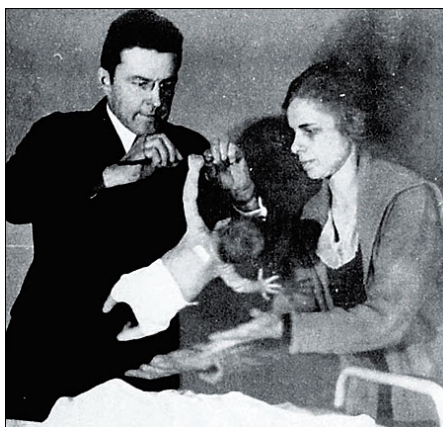
Infant Reflexes DVD Clip

Meltzoff & Moore (1983): Neonatal facial imitation



Tongue Protrusion Example: <http://www.youtube.com/watch?v=k2YdkQ1G5QI>

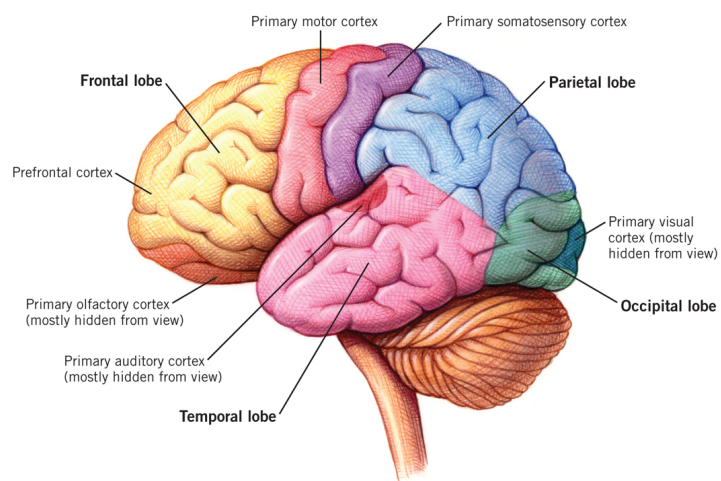
Why these reflexes?



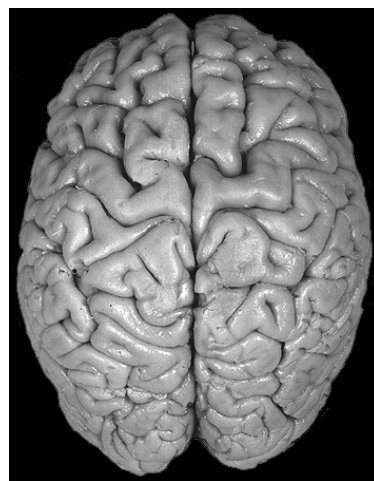
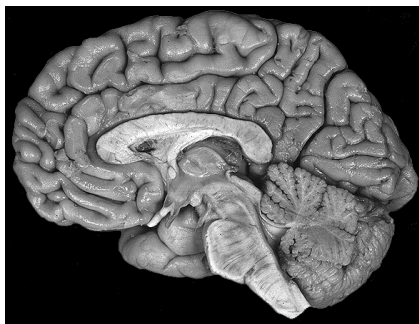
Questions on neonatal development?

**EARLY BRAIN DEVELOPMENT AND
EXPERIENCE**

Neonatal Brain Development (lobes of the cerebral cortex)



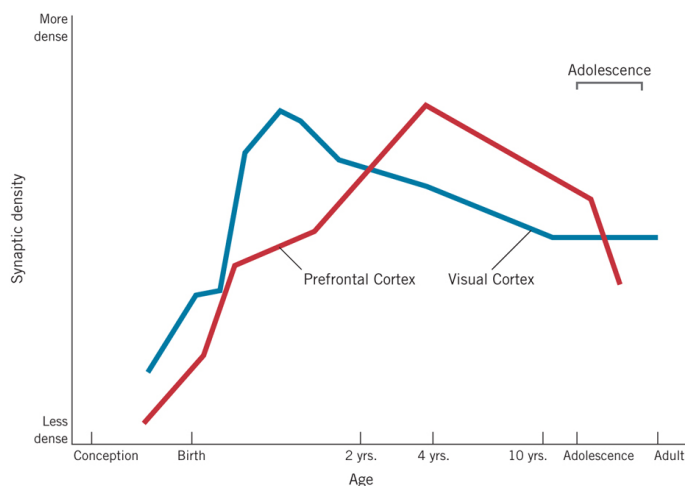
Hemispheres



Synaptic Pruning and Plasticity

- Synaptogenesis creates huge surplus of connections
 - Many unneeded connections between lobes
 - Young infants may experience synesthesia-blending of different senses-sound/color
- Pruning or death of connections starts in infancy and continues into early adulthood
 - “Cells that fire together, wire together” –D. Hebb
 - Inactive/less active may disappear to be “pruned away” (synaptic pruning)
 - Approximately 40% of connections die
- Different brain regions “prune” at different times

Pruning of Visual and Prefrontal Cortex



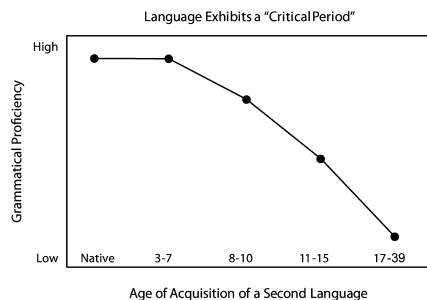
Why production of such excess?

- Production largely controlled by genes
- Which connects are pruned is largely controlled by experience
 - More **plasticity** or flexibility in the final wiring of the brain
 - Less information needed to be coded by genes
 - Brain can recover from early injury/earlier the better
 - May be needed to better adapt to environment

Behavioral consequences of pruning

- **Perceptual narrowing**
 - Ability to perceive certain distinctions in environmental stimuli becomes specialized or tuned to that commonly present
 - Accompanied by “loss” of distinctions outside the range of those commonly encountered

Example 1: Language (Kuhl et al.)



- Infants start out life able to distinguish between all sounds in all human languages (0-10 months)
- Become experts in their own language
- Lose the ability to discriminate between sounds in foreign languages (~10-12 months)

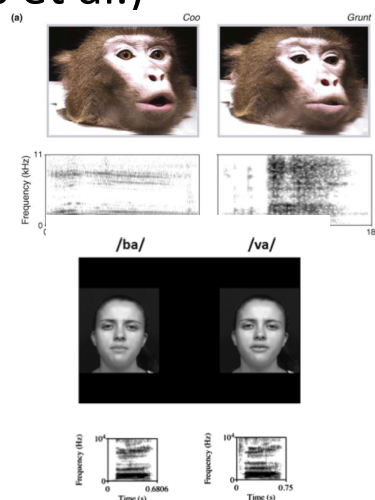
Example 2: Music perception (Hannon et al.)

- 6 month olds perceive changes in a variety of musical structures (e.g. foreign and non-foreign)
- By 12 months perform like adults
 - Western infants can only detect changes in the musical structure of Western music



Example 3: Multisensory integration (Lewkowics et al.)

- 6 month olds can match faces and voices of
 - other species sounds
 - foreign language sounds
- By 12 months
 - Ability is species-specific and language specific



Experience-Dependent Process

- Development resulting from the idiosyncratic experiences of the organism
- Plasticity conforms to individual's experiences
 - Phoneme discrimination
 - Music perception
 - Multisensory perception

Experience-Expectant Process

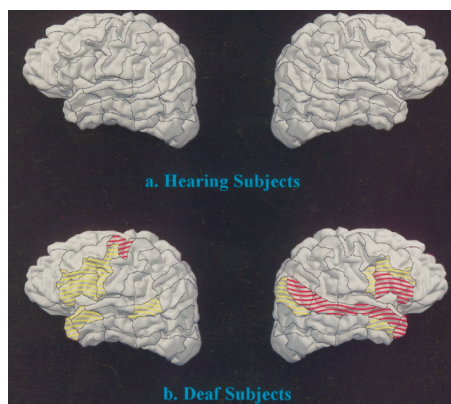
- Development resulting from the kinds of general experiences every member of the species is likely to have
 - Reliable experiences the brain can “expect”
 - EX: Patterned visual stimulation, faces, voices, other sounds, movement, etc.

Limitations to E-E processes

- Limitation: brain vulnerable if adequate stimulation is not present
 - Ex: born with cataracts-disturbance in basic visual input
 - longer the cataract remains, the worse the damage
 - » Permanent damage likely occurs because synapses that would have been activated by visual stimulation (but were not) were pruned
 - Dramatic improvement following early extraction

What happens to brain that does not receive expected input?

- If not used for typical purpose
 - May be co-opted for other purposes
- EX: Neville et al. (1998) study of congenitally deaf
 - Auditory cortex used for vision in those that learned ASL (visual-motor language system)



Critical periods/sensitive periods

- Windows of vulnerability in development
- Particularly sensitive to input during these periods
- Critical/Sensitive periods differ in...
 - Definition of boundaries
 - Consequences of deprivation

Critical period

- Experience/development must occur during defined period
- Developments that occur/do not occur during these periods are often irreversible/can not be established later
- Begin and end abruptly

Critical period example: imprinting

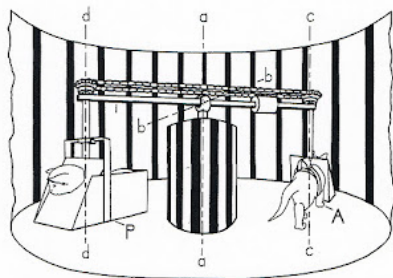
- Konrad Lorenz
- Studied greylag geese
- Investigated parent-offspring attachment shortly after birth
 - Geese would “imprint” or attach themselves to the first thing they see shortly after birth
 - Has to happen between about 0-36 hours
 - Results in animal maintaining physical closeness/following to imprinting being or object



Critical period for vision: Hubel & Wiesel's one-eyed kittens

- Controlled rearing experiment
 - One eye-lid sutured shut in kittens
 - After some duration, opened deprived eye
 - Varied the age of onset and duration of deprivation
 - Measured from cells in the visual cortex after eye was opened
- Found that the timing of the deprivation mattered
 - Newborn cats deprived of input for 6 months had little activity in visual regions of the brain associated with the deprived eye
 - Found that first 3 months of experience are critical to visual development
 - In contrast, mature cats (6 month olds) experiencing 1 year of deprivation caused no measurable change in the brain response/impairment

Held & Hein (1963)-Kitten Carousel

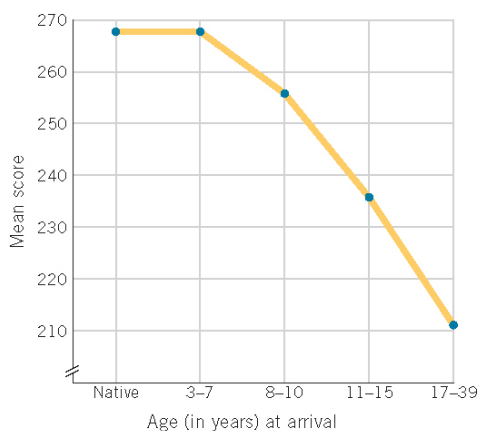


- Kittens reared in dark
- Only visual experience they were given was in the carousel
- Both kittens received the same visual experience
 - One moved itself
 - The other was moved by the carousel
- Only the kitten that moved itself developed normal depth perception
- Must experience this within ~3 months

Sensitive Period

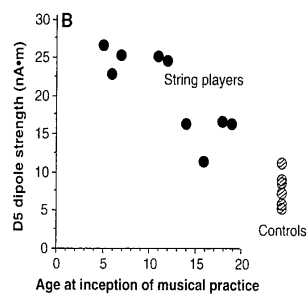
- Optimal time frame to receive necessary input/development to occur
- Begins and ends gradually
- EX: Second language acquisition

Sensitive period for 2nd language learning?

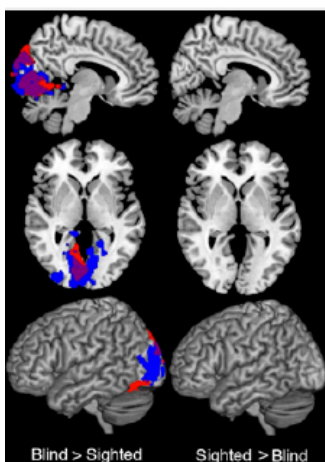


Sensitive or critical period for music?

- Increased cortical area for fingers of left hand in string instrument players (Elbert et al., 1995)
 - Not related to time spent practicing each day
 - Was related to age at which he/she began playing
 - But this also correlates with total years of playing
- Infants lose the ability to discriminate non-Western music changes if they haven't been exposed to them by 12 months
 - Two weeks exposure to non-Western music allowed Western 12 month old infants to perceive changes in non-Western music
 - Same exposure did not help adult perception



Studies of Language Processing in the Blind (Bedny et al., 2011, in press)



- Language activates left visual cortex in blind individuals
- But remapping depends on blindness in childhood
 - Congenitally blind (from birth)
 - Late Blind (after at least 9 years)
 - Sighted
- Presented sentences (language) vs. backward speech (non-language)
- Found that language activated visual cortex
 - To the greatest extent in congenitally blind
 - To a lesser extent in late blind
 - Not at all in sighted

Critical/Sensitive Periods and Education

- The concept of a “window of opportunity” led many educators to envision an irreversible process of education
 - Montessori-optimal periods
 - Discovery of harmful effects of prenatal and early development exposure to teratogens (tobacco, alcohol, lead paint, etc.)
 - Risk factors in development (e.g. poverty, abuse, neglect)
- Concept itself contributed to the modern educational emphasis on early experience and education in scientific and popular media
 - Head start/preschool programs
 - Modern early intervention for developmental delays
 - e.g. Autism

Modern thought on critical periods

- Sensitive vs. critical period is debated for many skills
 - Language and 2nd language development is likely the most hotly debated
- Critical periods are widely viewed as the exception rather than the rule
- Most developments thought of in terms of sensitive periods
 - Textbook does not mention critical period along with sensitive period in the opening chapters

Questions on early infant development and experience?

Conclusions

- Prenatal and early infant development is highly dependent on the experience/ environmental influence
- Certain experiences are required for typical development other experiences tune development
- Nature, type, timing of experience matters.